Mechanical Measurements and Metrology
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Module - 4
Lecture - 40
Measurement of Viscosity (continued) and Radiation Properties of Surfaces

This is lecture 40 Mechanical Measurements. Towards the end of lecture 39 we actually looked at the measurement of viscosity and we described an apparatus to do that the rotating cylinder viscometer. So what I will be doing in the present lecture is to consider one example, which is example 48 which is based on the rotating cylinder Viscometer. Then we will discuss about the radiation properties of surfaces and how they are measured. We are going to give some introductory ideas and we will describe what are the quantities of interest and some methods of measurement of these.

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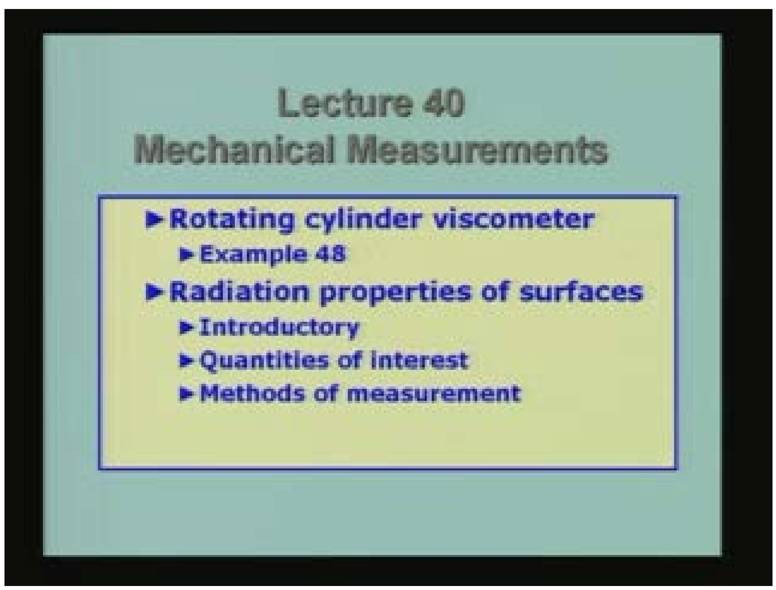

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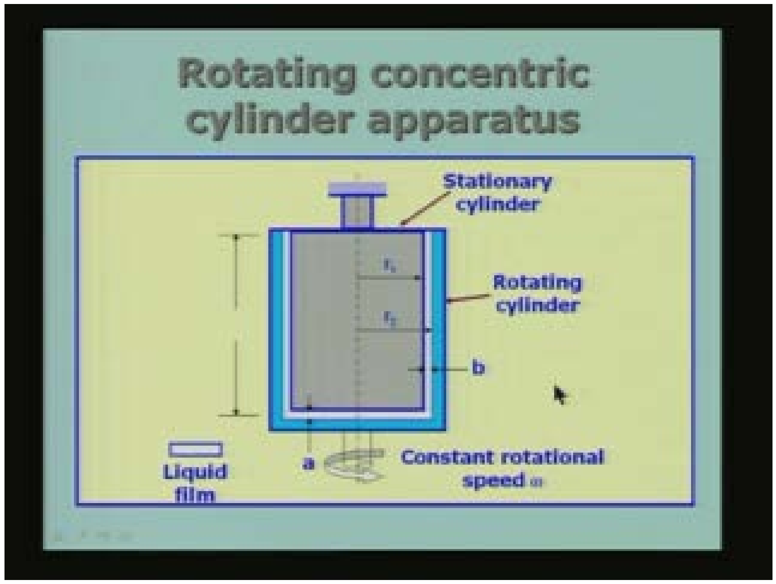

This is the rotating concentric cylinder apparatus which consists of a stator which is held stationary, and there is a rotor which is surrounding it and there is a gap in between the rotor and the stator and the gap is filled with fluid whose viscosity we want to determine. And there is a narrow gap which is given by the difference between the radius r_2, and radius r_1 and I call this gap, b. At the bottom again, there is gap a, which is again filled with the same liquid whose viscosity we would like to know, and the length is L. The outer cylinder is rotated at a constant rotation speed of omega, omega can be given in rpm or it could be given in radians per second. Of course, if one is given the other can be obtained easily.

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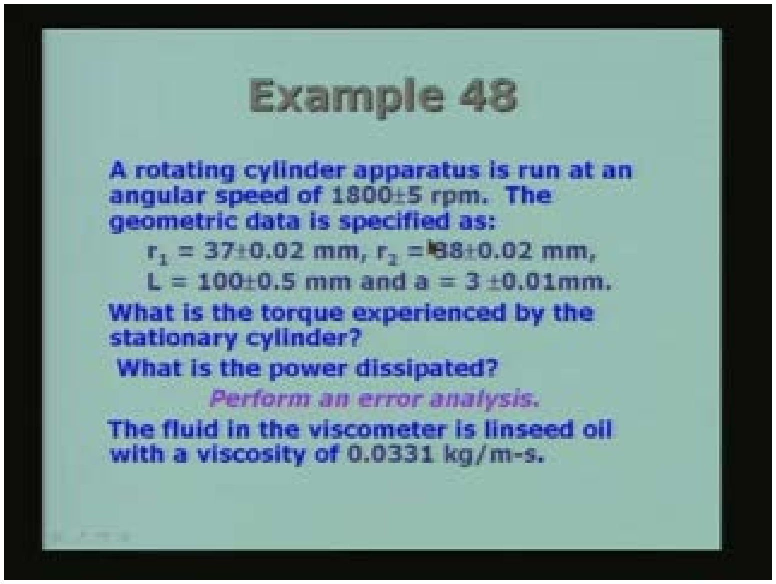

Here is the problem to look at: The apparatus which was shown in the previous slide is run at an angular speed of 1800 plus or minus 5 rpm. So this plus or minus 5 rpm apparently is the error in the measurement or may be there is a fluctuation in the rpm with respect to time. The geometric data is specified as under, the radius of the stator is 37 plus or minus 0.02 mm and the inner radius of the rotor is 38 plus or minus 0.2 mm, the length of the apparatus is 100 plus or minus 0.5 mm, and the gap a is 3 plus or minus 0.01 mm. So the torque experienced by the stationary cylinder is what we would you like to find out and also we would like to find out what is the power dissipated given that the fluid in the viscometer is linseed oil whose viscosity is known to be 0.0331 kg by msec.

I have also mentioned here that we would like to perform an error analysis. The error analysis is to bring out the effect of these plus or minus 5 rpm, plus or minus 0.02 mm, plus or minus 0.01 mm and plus or minus 0.5 mm. These are the errors in the various measured quantities. We would like to find out how the torque experienced by the stationary cylinder as well as the power is affected because of these measurement errors.

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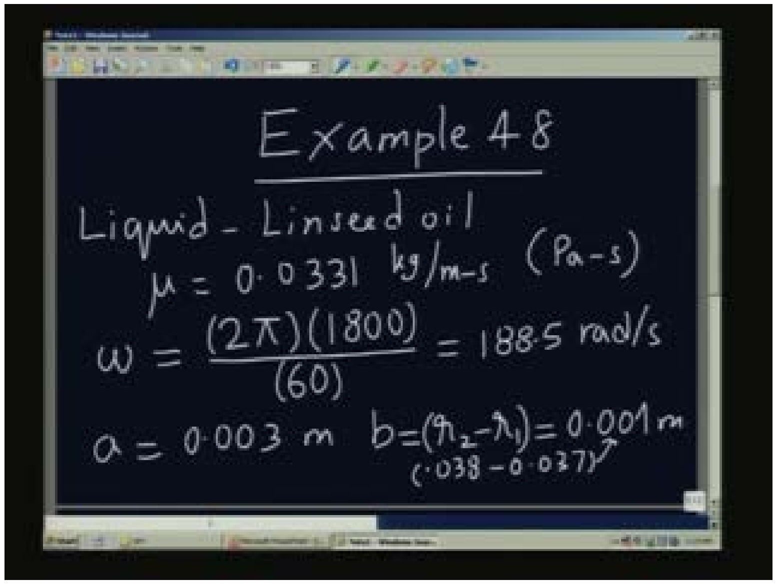

This is example 48; these are the different quantities which are given. The fluid is given or the liquid given is linseed oil, I have taken linseed oil, because it is a highly viscous fluid or viscous liquid and the viscosity mu is given by 0.0331 the units is kg by m-s or it is also Pascal-second that is the unit. So the other important thing which is required is the angular velocity omega given by each rotation rpm which means one revolution per minute, one revolution is 2π radians, so I am going to multiply by 2π, I am going to multiply by rpm which is 1800 rpm which is given in the problem and I am going to convert the value to radians per second.

Therefore, I am going to divide by 60 which is 60s in 1 minute. Therefore this will give you radians per second which happens to be 188.5 radians per second. So the other quantities of interest are gap a which is already given is 3 mm, so I will put it as 0.003 m in SI units, and the gap b is nothing but r_2 minus r_1 and the r_2 is 28 mm and r_1 is 37 mm so this will be 1 mm and that becomes 0.001m. So this is 0.038 minus 0.037 equal to that quantity. And the length of the apparatus (L) is given as 100 mm (Refer Slide Time: 11:38) or 0.1. And the torque T is given by mu into π into omega r_1 square into (r_1 square by 2a) plus ($2r_2L$ by b). And mu is 0.0331, π is 3.142, omega is 188.5, r_1 square is (0.037) into [0.037 square by (2 into 0.003) plus 2 into 0.038 into 0.01 by 0.001] Nm which is the product of force and distance and this works out to 0.086 N-m.

So the torque experienced by the motor which is trying to rotate the outer cylinder is given by 0.086 N-m or if you want to calculate in terms of Newton centimeter it will be 8.6 Newton centimeters. The power can be easily obtained, (Refer Slide Time: 12:38) the power consumed or power required is nothing but the product of torque times the angular velocity omega and the torque already calculated is 0.086 Newton meters multiplied by 188.5 radians by s so it will be N-m by s which will be nothing but watts and this comes to 16.2W.

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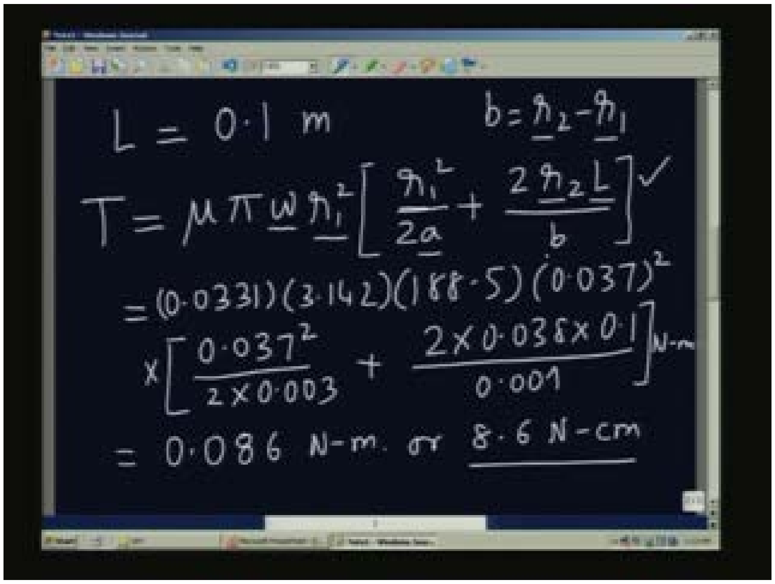

So in the case of a viscometer having linseed oil in the gap it requires about 16.2W or so much of power is dissipated because of the friction because of the viscosity of the fluid and I am rotating it at 800 rpm.

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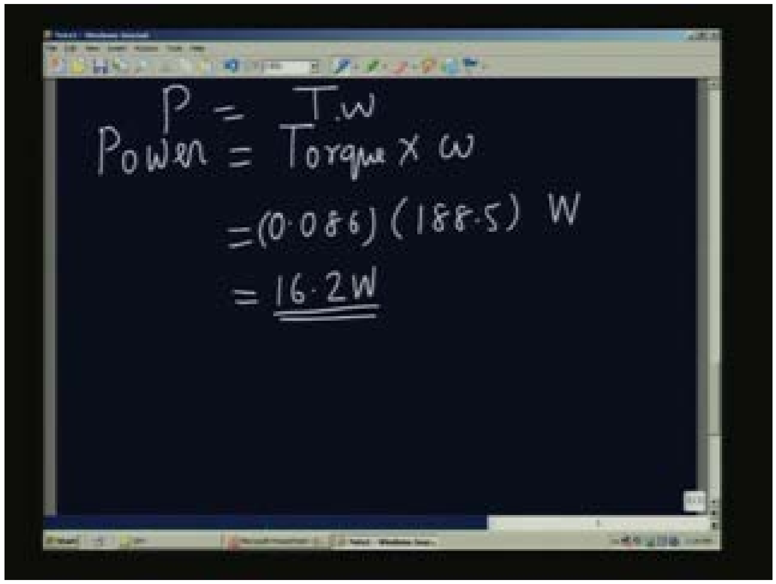

And if you see here, I have got the torque given by an expression, this is the expression I am talking about. A torque consigns the measured quantities which are going to come in the picture or r_1 because mu of course we are not give any error bar on that and therefore mu we will assume it as not prone to any error. So the quantities which are having some error are specified here and are underlined, omega is one of them then r_1 so again r_1 here. And if you remember a it is given directly and that is also having an error. Then r_2 also has some error and L is also having an error and b itself is nothing but r_2 minus r_1. So both of these have some error specified and therefore b is also a quantity having some error. So what you are expected to do is, to use the propagation of error formula and obtain all the influence coefficients with respect to omega, with respect to r_1 with respect to a, with respect to r_2, with respect to L and with respect to b of course is automatically covered by r_2 and r_1 and then use the error propagation formula and workout what will be the error in the estimated value of T.

And the next level is, when you want to calculate the error in the estimated value of the wattage or the power, again we use the power formula P is equal to T into omega and again you can see that we are using the same error propagation formula, the product of these two, in the previous step, you would have determined the error in T and error in omega is already given, so I can calculate the error in the power dissipated. The next topic of discussion is radiation properties of surfaces. Here are some introductory ideas. The introductory ideas are going to be both per say the radiation and then secondly for surface properties and further we are going to look at application of radiation measurement to the measurement of concentrations of gases using the absorption of radiation by gases.

So for most part I am going to look at only opaque surfaces because these are relevant from thermal engineering applications and of course sometimes we also use either transmission or semi transparent materials like glass and so on.

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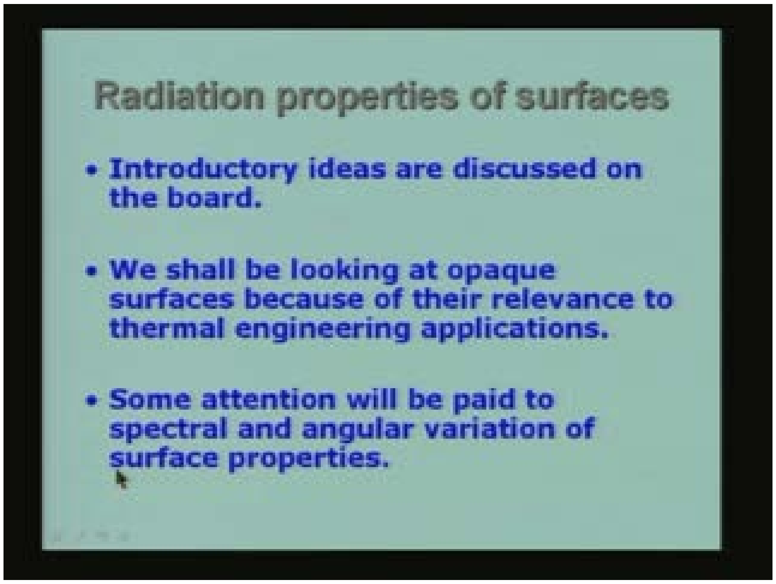

Our application basically involves opaque surfaces. Especially in mechanical engineering involving thermal engineering applications in opaque surfaces are more in use. We will also pay attention to spectral and angular variation of surface properties. These are very important. When we talk about surface properties we are talking about radiation being incident on some surface and also know subsequently what happens to that.

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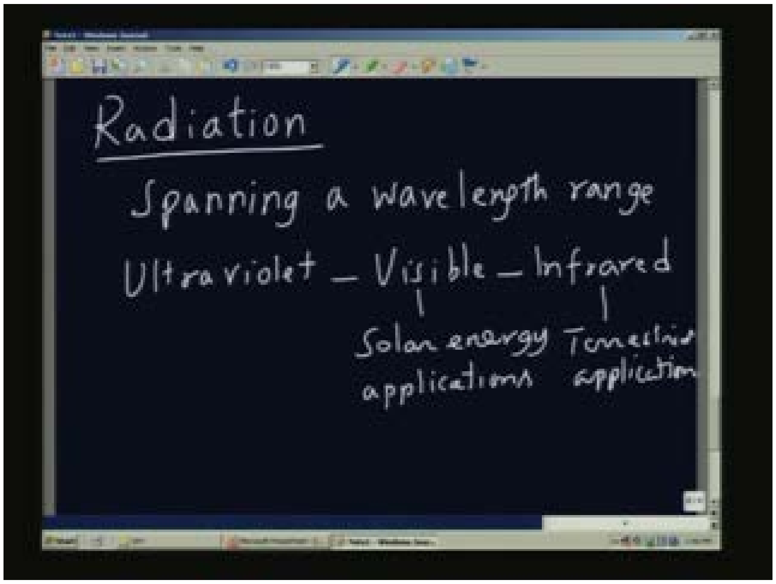

Here is some background on radiation. We are actually talking about spanning certain wavelength range. So the radiation which we are going to talk about may span from ultraviolet, we are going from low wavelength towards higher wavelength, then we have visible and then we have the infrared. So we can generally divide the wavelength range to three categories such as the ultraviolet range then the visible part of the spectrum and the infrared part of the spectrum. And the ultraviolet is of course useful in some applications. And especially if we are looking at the degradation of materials because of exposure to solar radiation for example there is a lot of ultraviolet radiation coming from the sun so such studies to require ultraviolet radiation and they require the steady of behavior of surfaces when ultraviolet radiation is impinging on them.

The second part, the visible part is also very useful, because mostly in solar energy applications we come across surfaces which either absorb or reflect solar radiation and depending on the application we may want absorption to actually take place or we may want reflection to take place, so that the radiation is not allowed to penetrate into the space in which we are interested. For example, if we have a building you would prevent solar energy from getting into the building if the idea is to keep the inside cool, especially in the tropics during the summer we would like to keep inside of the building cool, and therefore you would like to avoid the penetration of the solar heat into the building.

However, if you are considering the application to a solar collection device you would want the solar energy to be actually observed as much as possible so that it is available as useful heat energy for further processing. So, in the visible part of the spectrum we are very certainly interested and the properties of surfaces are very important, and they play a significant role in engineering applications. Also in space applications like satellite, thermal control and so on, the properties of surfaces which are exposed to solar energy play a very important role. Therefore from that point of view, we would like to look at the surface properties which are subject to radiation from the sun falling on that. The infrared part is another important aspect. For terrestrial applications, we have temperature close to 300 Kelvin which is the room temperature.

In these terrestrial applications, the radiation which is involved is mostly infrared part of the spectrum. Infrared cannot be seen but it can only be felt and it is important to consider infrared properties of surfaces, because most surfaces we use in engineering applications, either observe or reflect or emit radiation on their own because of their own temperature. In other words, if we look at the processes which we are going to take let us look at that. Suppose you have a surface, so if I put a surface here, I am just idealizing the surface be a straight line so on the inside of the surface there is a different medium. In other words, the surface actually separates two regions.

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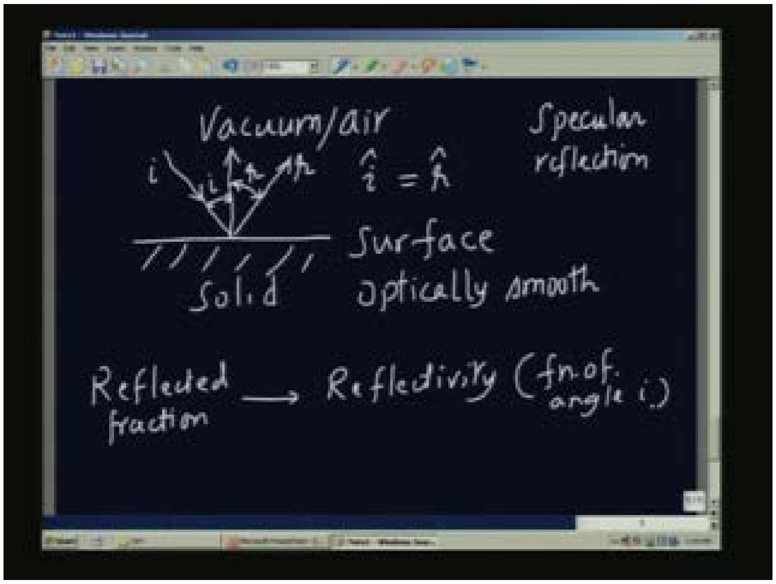

For example, I can consider vacuum here, or I can just consider air or atmosphere. For many purposes air is transparent, we have an engineering surface and the surface is going to separate two regions, one is vacuum or air and inside there is a solid, so here this is the solid material. So let us look at what is going to happen at this surface. If the surface is optically smooth, so if I assume it is optically smooth this is one possibility. Of course, in engineering applications, mostly we are not going to meet with optically smooth surfaces, but suppose we have an optically smooth surface if you draw the normal to this surface, if the light is incident or the radiation is incident at an angle of incidence is equal to i then it is reflected speculiarly. These are the two angles r this is reflected, this is incident, this is reflected light and the angle i is equal to r, so I put i as angle i is equal to r. So you have a specular reflection.

How do we characterize this reflection?
If some amount of energy is incident, or some amount of power is incident on the surface, the fraction of the power which is reflected is the reflectivity. So we can say reflected fraction. We will call it as reflectivity. So, if we are able to measure, both the amount of incident radiation as well as if we are able to measure the reflected radiation by taking the ratio one with the other then we will get the reflected surface and this is generally a function of angle i. It is the function of the angle. That means if I have a specular surface the reflectivity of the surface depends on the angle. That is, for an optically smooth surface reflection is specular, it follows the Snell's law cost of reflection. That means that the angle of incidence is equal to angle of reflection.

But the important thing to notice is that, the reflectivity is not constant but it depends on the angle. So, if we want to measure the reflectivity of the surface we must have an arrangement by which radiation is going to be incident at a desired angle with respect to normal, and I must make a measurement at the correct angle along this specular direction and look at how much energy is going to be reflected along that direction then take the ratio and get it and do it for different angles. Therefore, I must have an apparatus which must consist of a method by which I can have the energy coming at different angles in a nice small narrow beam and the reflected amount must be gathered and detected or measured by a photo detector and then we take the ratio of these two to get the reflectivity and this has to be done at different angles.

So, I must have a method or an apparatus must be able to change the angle as we require. That is what is involved in the case of a specular reflector. Suppose I look at the so called engineering surfaces normally what happen in the case of engineering surfaces is that they are rough, there is no smoothness, and there is no optical smoothness. Actually how do we characterize the roughness or the smoothness? When you have a rough surface, the rough surface will show some kind of undulations, even though it is a planar surface this is the mean line but the surface will show undulations, these undulations I will call it epsilon, if epsilon is much smaller than the wave length lambda, we call it as smooth surface, if epsilon is very large compared to lambda it becomes a rough surface.

And as we mentioned earlier, we may be talking about lambda varying from ultra violet part then the visible part and then the infrared, lambda is not a constant it depends on the particular application. So, if you want to consider some surface as smooth in the visible part of spectrum in the visible radiation then this quantity epsilon must be much smaller than that of the wavelength of the corresponding radiation.

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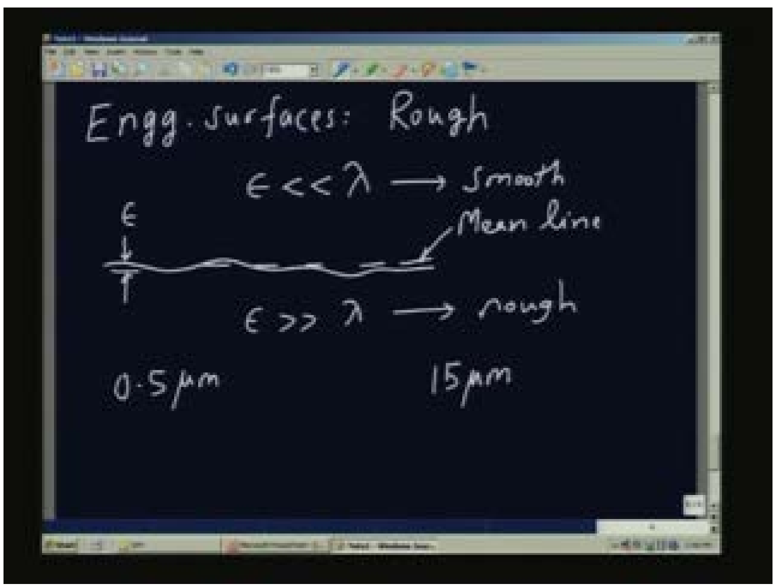

For example, if you take a visible part something like 0.5 micro meters that means the epsilon should be much smaller compared to 0.5 micro meters to consider the surfaces smooth in the visible part of spectrum. Suppose I go to the infrared part and I look at 15 micro meters the surface which is rough for visible radiation may appear smooth for infrared radiation. Because the wavelength is much larger the surface roughness element epsilon could be much larger and still it may appear as a smooth surface. So smoothness and roughness is a related term and the term is to be used with reference to the wavelength of the radiation.

Suppose, I consider engineering surfaces as rough surfaces, what it means is that the undulations are very severe such that they are much larger than the wavelength which I am interested in therefore the surface is not a smooth surface but it appears as having bridges and valleys and so on, so it will appear like this. So suppose I take a very small part of that and I draw a normal the normal to the mean line is this line, this is the mean normal. So the mean normal is given like this.

Suppose I draw a normal to the infinite small area which I have chosen at a particular place the normal is oriented like this, this is the local normal. So the mean normal and the local normal are not the same and the direction of the local normal will keep varying. So suppose this is the surface and suppose I draw the normal here it is like this, here the normal is like this and here the normal is like this. Suppose I have parallel radiation falling on it in this direction, radiation is falling along the direction this will be reflected like this, this angle will be equal to this angle and it will be reflected in this direction whereas here this will be reflected like this and here it will be reflected like this, these angles are same.

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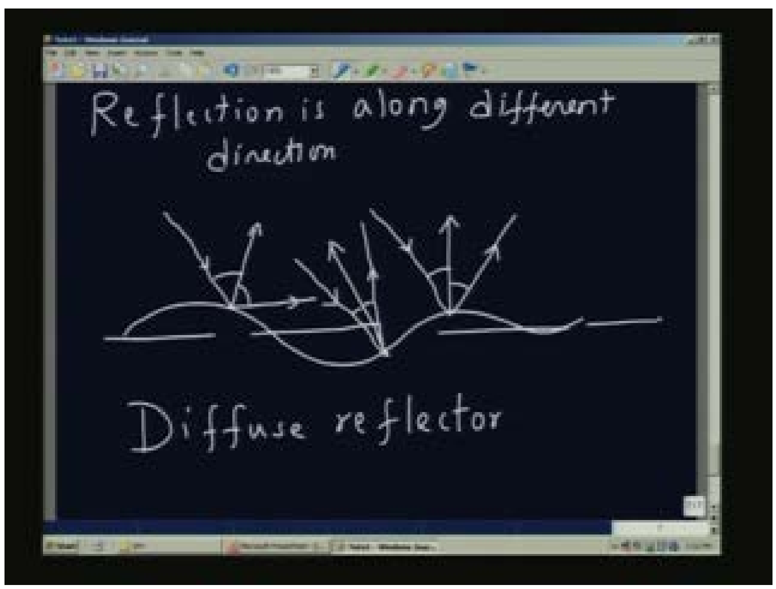

Therefore even though parallel radiation is falling on it this is going in this direction, this is going in this direction, this is going in this direction therefore you see that the reflected radiation is going in all sorts of directions. So reflected direction is along different directions. In principle, if we define a surface being totally rough engineering-wise, then what it means is that the radiation which is reflected will be going in all directions and therefore we call such surface as a diffuse reflected. So we have two extremes. We have an optically plane surface or optically plane smooth surface and we have an optically rough so called plane surface but of course the mean line is here, even here I can draw a mean line, this is the mean surface but the actual surface is undulating.

It is a three dimensional surface, I am just drawing the cross section. It means this is going to happen in all directions, whichever cross section you take of the surface, there will be undulations. Therefore if a beam of light is falling at the particular angle, it will be redistributed into all the different angles possible and we say such a reflector is a diffuse reflector. So completely the reflected radiation does not show any dependence on the direction in which it has come on the surface. That directionality is completely forgotten. Of course, the amount which is reflected may be dependent on the incoming direction. But as far as directionality is concerned, it is reflected equally well in all the directions, therefore we call it the diffuse reflector.

The perfect diffuse reflector is one which will reflect in all directions in a diffused fashion. These are the two extreme cases, and obviously we can think in terms of some kind of an intermediate behavior. Suppose, I have a surface which is optically smooth in one region, and optically rough or totally rough in another region, there may be some wavelength region where it will be neither totally optically smooth nor totally optically rough and therefore it will probably show an intermediate behavior. So let us just see what will happen.

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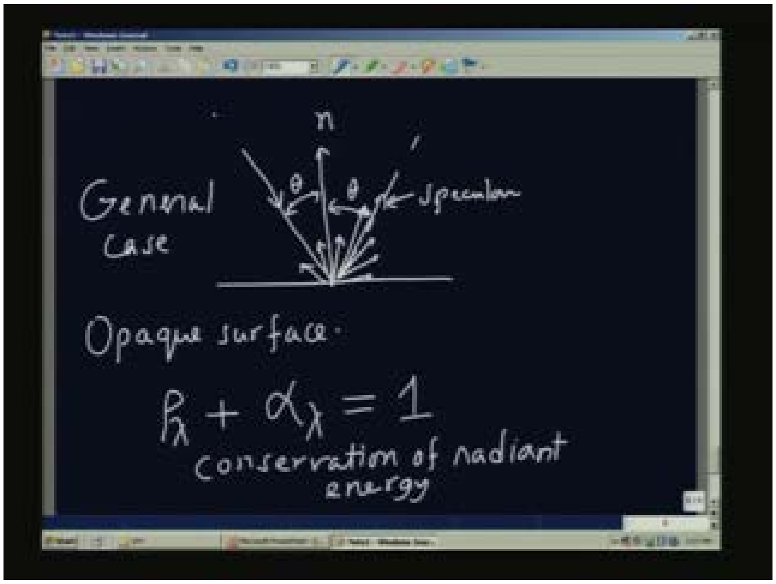

If I draw that surface I have got radiation coming in this direction, this is the normal to the surface I will call it as the normal, this is the angle theta at which it is falling on it. Now what will happen if I draw a line corresponding to the specular direction, this is also equal to theta so there will be more reflection along this direction and less along the other direction therefore you may get a reflection like this? The reflection may show some specular component, and at the same time, it also shows reflection along the other direction. This is the most general case. It is neither optically smooth nor rough so it is some kind of an intermediate case.

So the incoming radiation when it is reflected will show two types of behavior. One is a component along the specular direction which is more than what normally would be found along the other direction and the presence of reflection along the other direction. Therefore in this case for a single incoming direction reflected radiation goes along all the direction but with different strengths or different reflectivities. Therefore this is the most general and most difficult to characterize or measure.

Let us look at some more quantities. Suppose we have an opaque surface, what does it mean? It means that, the reflectivity I will call it as rho plus what is absorbed I will call it as alpha. So these are fractions, rho is the amount which is reflected from what is incident on the surface and alpha is absorbed therefore this must be equal to one because the two fractions must add up to, this is nothing but conservation of radiation energy or radiant energy. So what is incident on the surface should either be reflected or should be absorbed because it is a opaque surface, nothing is penetrating into the surface therefore it is either reflected or absorbed at the surface so rho plus alpha is equal to 1.

Now what it means is that I need not measure both rho and alpha separately. If you measure one, the other one can be estimated because it is nothing but 1 minus alpha. Of course, this statement is somewhat not accurate because there is directionality and there is also dependence on wavelength. Therefore if you want here you can say rho_{lambda} plus $alpha_{lambda}$ is equal to 1 for a given wavelength. At a surface either reflection or absorption should take place. There is a third property which is because of the temperature of the surface itself you will have emission.

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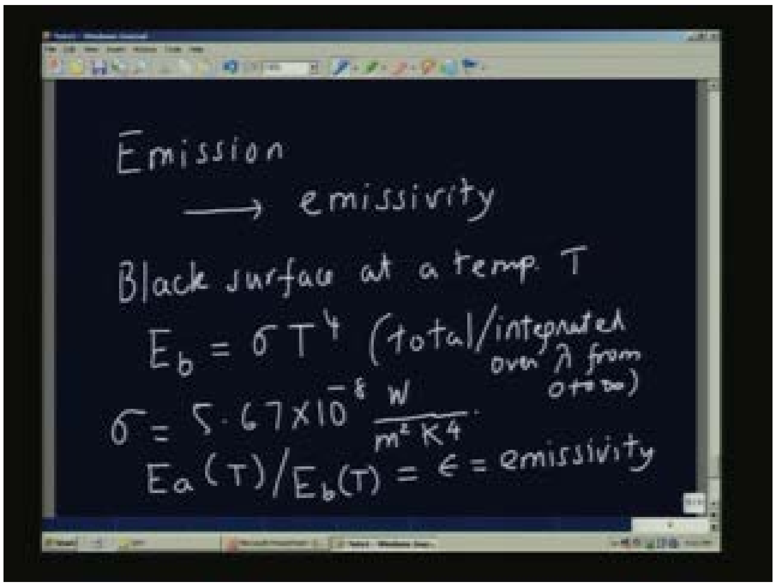

Any surface at a temperature above 0 Kelvin will radiate and emission is characterized by a property called emissivity. So what I am going to do is to look at how to define this quantity called emissivity. Emissivity means it has something to do with the amount of radiation emitted from the surface. Now how do I characterize? One way of doing it is to compare the actual surface to the black surface or a black body. From physics, we know that the black body or black surface at a temperature T, I am now looking at only total radiation coming from the surface, we will look at the monochromatic on the spectral values late. Suppose we have black surface at a temperature T it emits E_b is equal to sigma T power 4. The total amount of radiation leaving the black surface per unit area is simply given by sigma T power 4 where sigma is the toughen Boltzmann constant and T is the absolute temperature of the surface.

So emissivity can be defined, this is the total or it is also called integrated that means integrated over lambda from 0 to infinity, from the lowest possible to highest possible wavelength. Of course, in practice 0 to infinitive may mean something like from 0.01 to 100 micro meters when you consider that region. In some cases it may be even narrow than that depending on the temperature. So I am having a black surface, which emits radiation per unit area, this is W by m square given by sigma T power 4 where sigma is toughen Boltzmann constant and in fact the value of sigma is 5.67 into 10 to the power minus 8 W by m square Kelvin power 4. Now, suppose the amount emitted by the actual surface is E_a this is again so many W by m square of the actual surface at the temperature T. If I divide it by E_b at the same temperature T, this we call as emissivity epsilon. So in this case I am looking at the total emissivity. Total means including all wavelengths which are possible.

Of course, now this definition can be particularized to a particular wavelength also so what I have to do is to find out how much energy or power is radiated from the actual surface in a small wavelength region and compare it with the black body and the amount which is radiated by the black body in a certain small wavelength is given by plank distribution function. So this ratio will be, the actual surface will give some value of emission in that narrow band of wavelength at lambda and that divided by corresponding Planck radiation will give you the emissivity at that particular lambda.

In other words, we can also define what is called $\text{epsilon}_{\text{lambda}}$ which is also call the monochromatic emissivity. This background is sufficient for us to look at the monochromatic emissivity, and correspondingly, we can also define monochromatic absorbitivity and monochromatic reflectivity and there is a law called Kirchoff’s law which says that monochromatic emissivity and absorbitivity are exactly the same.

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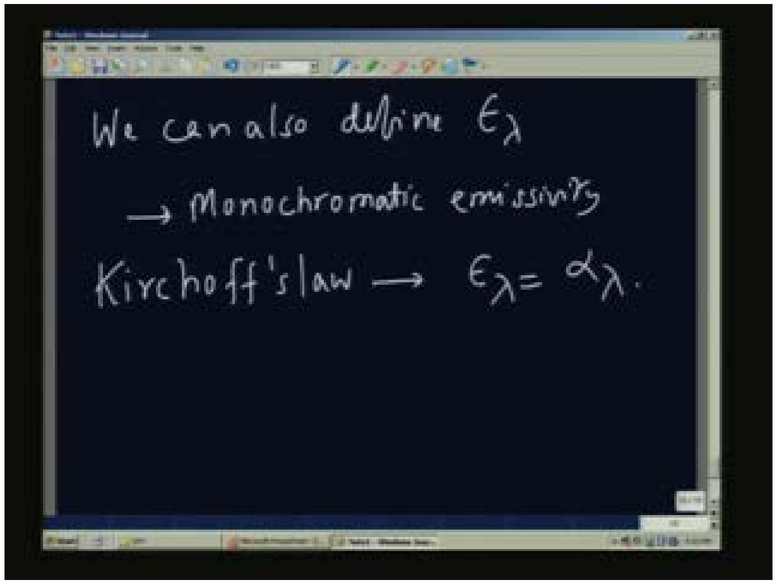

So epsilon$_{lambda}$ is equal to alpha$_{lambda}$. This is your Kirchoff's law. It says that epsilon$_{lambda}$ equal to alpha$_{lambda}$. Now let us look at the things we require if we want to make a measurement of surface property. Requirement in terms of hardware: We are talking about hardware. What we require for making measurement of radiation is first of all we require source of radiation. When we discussed about parametry we talked about the black body sources. So we can have a cavity radiator which will give black body radiation, and that could be a source of radiation.

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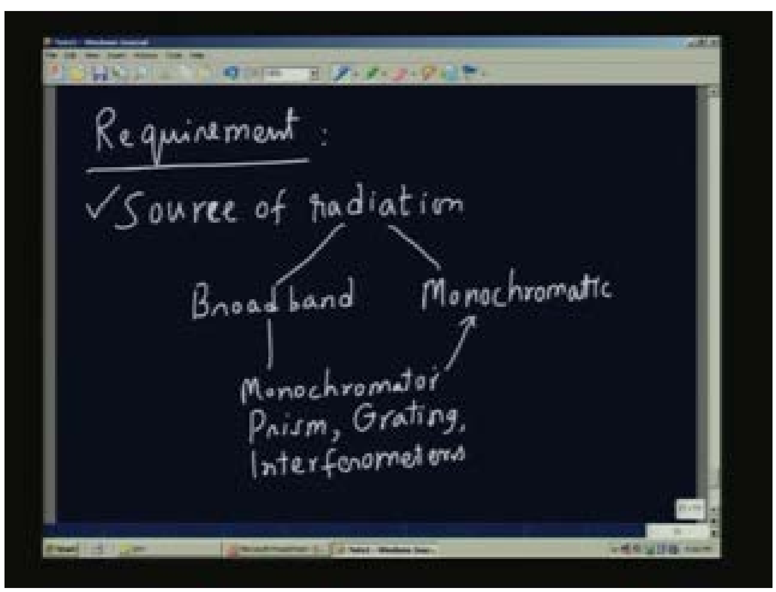

Of course, that is normally not used in practice. We may use some other source of light like for example, we have the tungsten filament lamp or we can use a growing resistor which is heated by electrical means and it glows and gives radiation and so on, it is also called a glow bar. Therefore various sources are used. For example, if you want source in the UV region you require special lamps which will give ultra violet radiations. In the visible part of spectrum we are familiar with the various kinds of things. For example we have the tungsten filament lamp which gives you good visibility. Similarly in the infrared part of the spectrum we can use a hot object itself as a source of radiation.

We can also use lasers. Lasers can be in different parts of the spectrum and we can also use laser as a source of radiation. Number one is we require source of radiation. Number two of course, there can be two types of sources, one we call as the broad band that means spanning a large wavelength range for example, a black body is a broad band source or you may want a monochromatic source. So there are two ways of going about. You can use a broad band source and use a monochromator. For example, a spectrometer which uses for example a prism which is very familiar to all of us. It can be grating, or in modern times we also use interferometers.

These are used as monochromators or you can have a monochromator source itself. For example, if you take a bulb filled with sodium and the sodium vapor is going to give raise to radiation it has got a specific wavelength at which it is going to radiate and therefore it is already a monochromatic radiation. Or you take the case of lasers they are monochromatic sources of radiation. They have specific wavelengths or specific frequency at which it will give you light. Therefore either you can have a broad band source from which using a monochromator or spectrometer you make a monochromatic source or directly use a monochromatic source of radiation, this is the first requirement.

The second requirement is some optical arrangement, which may involve slits and it may involve lenses, mirrors etc. This is normally called as steering. The radiation which is coming from the source needs to be taken to some particular space where you want to conduct the experiment. For example, you must make it incident on a surface so you must steer it by using lenses, slits, mirrors etc. Actually some optical arrangement is required and therefore radiation measurement always involves some optical arrangement and in fact this is the reason why radiation measurements are very expensive.

Radiation experiments are monochromatically very expensive and then the optical arrangement involving lenses, mirrors etc are very expensive and therefore the measurements we are talking about are all mostly very expensive measurements in terms of the amount of money required to set up the experiment.

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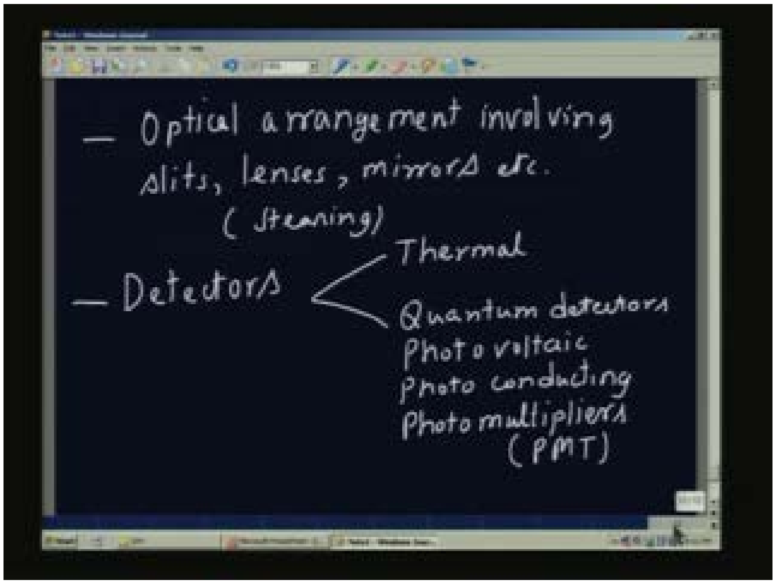

Then we require most importantly, the detectors. Detectors can be broadly classified into two categories. Like the broad band and monochromatic here also we have what are called thermal detectors. Thermal measurement means you are going to convert or the effect of the radiation will be to heat something and that temperature is going to be measured, and from this, I am going to find out the amount of radiation which is falling on it. And the second type is called the quantum detectors, which rely on either photo voltaic or photo conducting or photo multiplier effects.

These are all quantum detectors that actually detect the photons through any of these three. The photo resistive means that resistance of an element will change then photons are impinging on that one or photo voltaic that means the voltage will be generated when photons going to fall on the detector or it may be photo multiplier where electrons are rejected and these are accelerated using electrical fields and they actually impinge on secondary electrodes and they multiply by the number of electrons. Therefore they are called photo multipliers.

We can say photo voltaic and photo conducting that means the resistance of some element is going to change in the presence of radiation field or it may be photo multipliers; these are also called PMT's. These photo multipliers come with different materials, so that they will respond in different regions of the electro magnetic spectrum. The photo multiplier is the most sensitive in all these things which we are talking about.

Many times what we do is we cool the detector to very low temperature so that the noise can be reduced, usually it is done by cooling the detector to liquid nitrogen temperature. So you see that detector itself is photonic, the quantum detector needs cooling arrangement liquid nitrogen is required and it is expensive. We are talking about very expensive equipment. These are the parts which are required. Apart from this, we also require some accessories like, in the case of reflection

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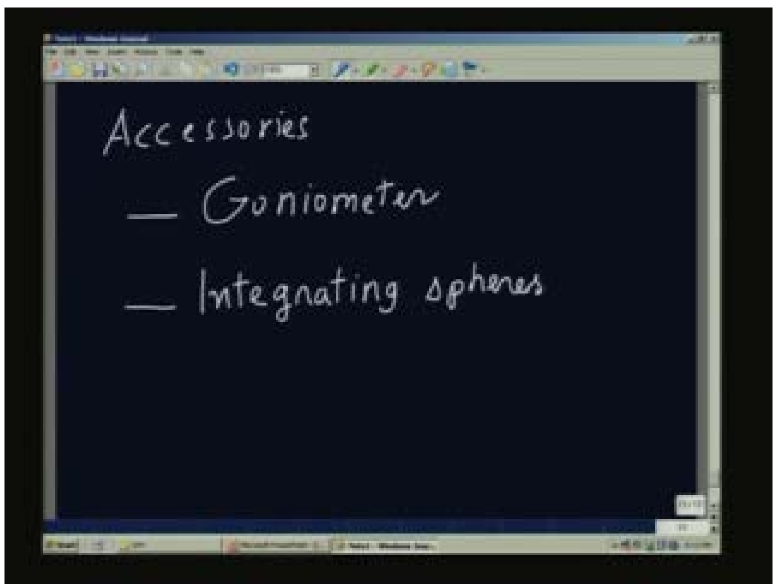

measurement, I have to have an arrangement by which radiation can be coming at certain angle, and I must be able to measure the reflected part at another angle so there may be some method for measuring these angles accurately and we have what is called the Goniometer. Goniometer is an arrangement, by which we can illuminate and study the reflection at specified angles, measure the angles accurately and that is done by Goniometer. Of course, the Goniometer related measurements are the most accurate and they are usually used as the basis for other methods or calibrating other devices. Or we can also use, one simple gadget which is called, the integrating sphere.

So these accessories by themselves, are not useful, they have to be used along with the rest of the things we discussed. You need the source, the monochromator then you must have some kind of a steering arrangement for making the light take a particular direction, and then you must have a detector. The Goniometer or the integrating sphere comes in between these things. There is the source of light and on the other extreme is the detector of light or measurement of light and in between these two different numbers of things are present and one of them could be a Goniometer, one of them could be an integrating sphere, it could be monochromator, and so on and so forth.

Many times what we do is, because we have to measure two quantities if you remember the reflectivity you need to measure the incoming radiation as well as the reflected radiation so you must measure two things. So you require either two detectors or the same detector must receive both alternatively So that you can measure one or the other and then find out what is the ratio. This is a very challenging task. Therefore these methods of measurement require apparatus which are made very carefully in specialized laboratories and workshops and they are supplied at great cost and therefore radiation involves very expensive equipments.

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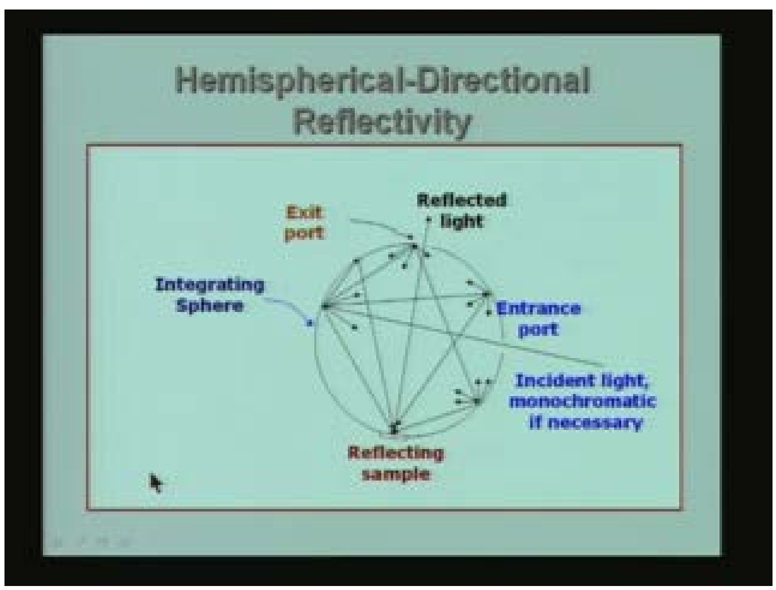

Now let us learn about an integrating sphere.

What does an integrating sphere do or what does it contain?

Actually by the name, integrating sphere it is a spherical shape chamber. So I have just show it as circle here and it has got an opening for light to enter.

What happens when the light enters in the integrating sphere?
The inside of the integrating sphere is given a coating which has got two important properties. One, it is very highly reflecting, let us say 95% or 97% or 99% reflectivity, and number two, it is a perfectly diffuse reflector. That means if the radiation falls on this surface it is distributed immediately to all the directions possible. So, an integrating sphere is essentially a spherical chamber and you have an arrangement which allows light to integrate through a small port or entrance port as shown here, and when it falls on the inside surface it gets reflected in all directions.

Basically, this is the principle of the integrating sphere. Now what will happen is that it falls on the surface it is reflected in all directions and the reflected light may fall on any other part of the sphere after reflection because it is going in all directions. Suppose I follow this, one ray came here and it got reflected here then it undergoes another reflection, or it goes here or it goes to another reflection. So, a large number of reflections are going to take place inside. And if you look at any part of the sphere, the radiation which entered at one particular spot gets completely redistributed throughout the sphere, and there will be near uniform illumination inside of this radiation.

So what I am talking about, is a device which is able to give me, by the design of that particular device across you have a certain coating, certain high reflectivity as well as, highly diffusive coating, it is able to give you uniform illumination inside and therefore, you can immediately see that if I put a reflective sample at any one part of the sphere, I make a small hole and I introduce my sample and the radiation which is falling on it will be a perfectly diffuse radiation. Now suppose, I look at the radiation reflected from this sample by making another hole here and allowing the some radiation to escape, I will be able to measure the hemispherical directional.

That means that the surface is illuminated throughout the hemisphere. It is illuminated from all directions, and then in one particular direction, I will find out how much is the amount of reflection. And by measuring the amount which is incident and the amount which is reflected I will be able to characterize what is called the hemispherical directional reflectivity. In this case, I allowed the radiation to impinge on the reflecting surface from all directions ,and I measured the reflected light. I can also exactly do the opposite. I can allow light to be impinging on this sample and after reflection it will get reflected in all directions of the reflected sample.

This is going to be gathered by this sphere and the sphere is going to respond entirely to the amount of energy which is reflected in the surface in all directions. Therefore if I make a hole here and if I allow the reflected light to pass through I will be sensing or I will be measuring a quantity which is related to the hemispherical value corresponding to the reflecting sample. So it is coming at a given angle with respect to the normal and the reflection in all directions is covered by the integrating sphere. In fact this is the reason why it is called the integrating sphere. It integrates over the hemisphere on the surface. So it measures all radiations coming in all directions of the hemisphere from a particular surface of the sample which is kept in a part of the spherical, enclosure. Thank you.